Weak Reprocessed Features in the Broad Line Radio Galaxy 3C 382

Paola Grandi

Istituto di Astrofisica Spaziale, CNR, Area di Ricerca di Tor Vergata, Via Fosso del Cavaliere 100, I-00133 Roma, Italy

paola@ias.rm.cnr.it

Laura Maraschi

Osservatorio Astronomico di Brera, Milano, Italy

maraschi@brera.mi.astro.it

C. Megan Urry

Space Telescope Science Institute, Baltimore, USA

cmu@stsci.edu

Giorgio Matt

Universita' degli Studi "Roma tre", Roma, Italy

matt@amaldi.fis.uniroma3.it

ABSTRACT

We present a detailed X-ray study of the Broad Line Radio Galaxy 3C 382, observed with the *BeppoSAX* satellite in a very bright state. The continuum emission is well modeled with a power law that steepens at high energies, with an e-folding energy of ~ 120 keV. At soft energies a clear excess of emission is detected, which can not be explained solely by the extended thermal halo seen in a *ROSAT/HRI* image. A second, more intense soft X-ray component, possibly related to an accretion disk, is required by the data. Both a reflection component ($\Omega/2\pi = 0.3$) and an iron line (EW~ 50) are detected, at levels much weaker than in Seyfert galaxies, suggesting a common origin. Combining our measurements with results from the literature we find that the iron line has remained approximately constant over 9 years while the continuum varied by a factor of 5. Thus the fluorescent gas does not respond promptly to the variations of the X-ray primary source, suggesting that the reprocessing site is located away, likely at parsec distances. While the continuum shape indicates that X-rays derive from a thermal Comptonization process, the weakness of other spectral features implies that either the upper layers of the optically thick accretion disk are completely ionized or the corona above the disk is outflowing with mildly relativistic velocity.

Subject headings: galaxies: active — galaxies: individual (3C 382) — galaxies: Seyfert — line: profiles — X-rays: galaxies

1. Introduction

Recent observations with *BeppoSAX* (Grandi 2001, Zdziarski & Grandi 2001) and *RXTE* (Eracleous, Sambruna & Mushotzky 2000) have shown that the circumnuclear environments in Broad-Line Radio Galaxies (BLRGs) are different from those of their radio-quiet counterparts, Seyfert 1 galaxies. In particular, in radio-loud AGNs the reprocessed features can be absent or weak, while in radio-quiet AGNs the iron lines and the reflection components are generally intense and always detected (Matt 2001). These results have important implications for understanding the physical distinction between radio-quiet and radio-loud AGNs, that is why strong radio sources (lobes, jets, etc.) arise somehow only in a small fraction of AGNs.

Broad Line Radio Galaxies share some of the properties of radio quiet Seyfert galaxies, i.e. broad optical emission lines and an optical UV bump suggesting the presence of a similar optically thick accretion disk in both cases. Yet the accretion disks may differ in the physical conditions in their inner regions: hence the diagnostic importance of X-ray spectra which originate much closer to the central black hole.

The inner accretion disk in radio galaxies may be hot, optically thin and dominated by Advection (ADAF) as proposed early by Rees et al. (1982) and studied in detail more recently (Narayan 1997; Narayan, Mahadevan & Quataert 1988). The double-peaked broad lines observed in some BLRGs can be explained if the lines are produced in a cold outer disk surrounding a hot ion torus (Eracleous & Halpern 1984).

X-ray observations of a narrow (although intense) iron line and a weak UV bump in 3C 390.3, the prototype of double-peaked radio galaxies, support the idea that cold accreting material is not present in the vicinity of the black hole (Eracleous, Halpern & Livio 1997; Grandi et al. 1999). A hot accretion flow might also explain the *BeppoSAX* spectrum of 3C 120, which shows a weak iron line and reflection component (Zdziarski & Grandi 2001).

However the weakness of discrete features in the X-ray spectra of radio galaxies could also be due to dilution of a "normal" Seyfert continuum by a pure power-law X-ray component possibly due to non thermal emission from the jets known to be present in these systems.

This hypothesis was not favored however in the cases of 3C 390.3 and 3C 120 (Grandi et al. 1999, Grandi 2001, Zdziarski & Grandi 2001). In 3C390.3 the iron line, although narrow is rather intense. In 3C120 the high energy cutoff observed by *BeppoSAX* excludes a significant power law jet component.

Here we discuss in detail the *BeppoSAX* observation of the Broad Line Radio Galaxy 3C 382 (z=0.0579). Preliminary results, together with an overall review of *BeppoSAX* spectra of BLRGs were presented in Grandi (2000). 3C382 is a radio galaxy with lobe-dominated FRII morphology. The inclination angle of its radio jet is estimated by Eracleous and Halpern (1988) to be $i > 15°$, assuming the radio structure is not bigger than the largest double-lobed radio galaxies. A relatively large inclination is supported by the low ratio of core to extended radio flux, $R \equiv F_{core}/(F_{total} - F_{core}) = 0.07$ at 6 cm (Rudnick, Jones & Fiedler 1986), as compared for instance to $R = 2.69$ for the well known OVV quasar 3C 279 (Morganti, Killeen & Tadhunter 1993). At optical-UV wavelengths, 3C 382 has broad (FWZI$> 25,000$ km sec^{-1}) emission lines which are variable on time scales of months to years. Its nuclear continuum is also strong and variable (Yee & Oke 1981, Tadhunter, Perez & Fosbury 1986). A recent HST WFPC2 image shows that 3C 382 is an elliptical galaxy strongly dominated by an unresolved nucleus (Martel et al. 1999).

The X-ray spectral properties of 3C 382 are not yet well established.

Previous satellites produced contradictory results on the soft emission. Some authors found signature of warm absorber (Nandra & Pounds 1994, Reynolds 1997), others an excess of emission that was fitted with both a broken power law and a thermal model (Urry et al. 1989, Kaastra et al. 1991, Barr & Giommi 1992, Woźniak et al. 1998, Sambruna et al. 2000). Recently Prieto (2000) claimed that the soft excess could be entirely related to an extended thermal emission seen around the nucleus of 3C 382 in a *ROSAT/HRI* image.

At higher energies, the situation is also more confused. Both *Ginga* and *ASCA* and RXTE have detected an iron line, although with dif-

ferent profiles and intensities (Nandra & Pounds 1994, Lawson & Turner 1997, Reynolds 1998, Woźniak et al. 1998, Eracleous et al. 2000). The *ASCA* iron line was extremely broad ($\sigma \sim$ 1.8 keV) and more intense by about a factor 3 than that measured by *Ginga* .

The following sections describe the *BeppoSAX* observations, data analysis, and interpretation.

2. Observations and Data Reduction

3C 382 was observed on 1998 September 20-22 with the *BeppoSAX* Narrow Field Instruments (NFS): LECS (0.1-10 keV), MECS (1.5-10 keV), and PDS (15-300 keV). The LECS (Low Energy Concentrator Spectrometer) and MECS (medium Energy Concentrator Spectrometer) are imaging instruments and the PDS is a phoswich detector system with collimators pointing on and off the source. At the time of the 3C 382 observations, only two units (MECS2 and MECS3) of the MECS were working. Table 1 shows the net exposure times and count rates of LECS MECS and PDS, respectively.

To test whether fast flux variations occurred, we applied a χ^2 test to the light curve for each instrument separately. We set the threshold for significant variation at a probability of $\leq 10^{-3}$ that the count rate was constant, independent of the temporal bins used (we used bins of 1000, 5000 and 10000 seconds). According to this criterion, no significant variations occurred during the *BeppoSAX* observation of 3C 382, even though this source is known to be active on the time scale of a day (Barr & Giommi 1982, Kaastra et al. 1991). Note that flux variations of about 20% as observed by *EXOSAT* could have been easily detected by the MECS instrument (see Figure 1). Given the stationary state of the source, we summed the 0.1-120 keV spectrum over the entire observation.

Data from each instrument were reduced following standard procedures (Fiore, Guainazzi & Grandi 1999). The LECS and MECS spectra were accumulated from circular regions of 4'. A recent analysis by Prieto (2000) of the *ROSAT/HRI* images has demonstrated the presence of extended thermal emission around 3C 382. As the FWHM is about 100 arcseconds, it is not resolved in the *BeppoSAX* images and therefore contributes to the LECS spectrum. The *Einstein/IPC* data re-

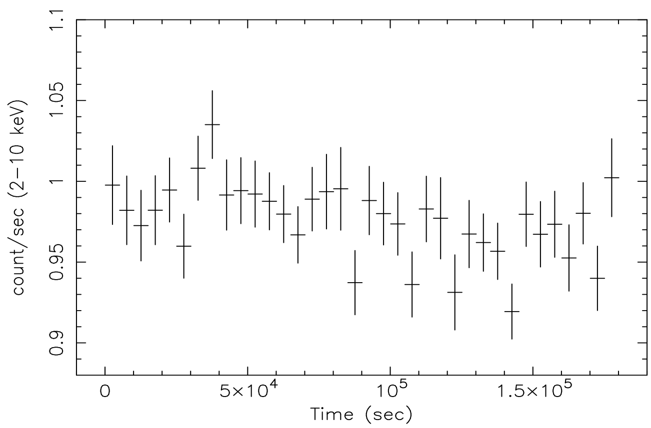

Fig. 1.— The MECS light curve shows no significative evidence of fast variability. The bin size is 5000 sec and the length of the pointing about 2 days. The net exposure time is $\sim$ 86 ksec: gaps in the data are due to Earth occultation and high background.

vealed several serendipitous point-like sources at distances of about 3' from the radio galaxy. Their contribution to the *BeppoSAX* spectra should be negligible since their *Einstein/IPC* count rates are about 30 times lower than those of 3C 382. Even assuming a very flat power law $\Gamma = 1.5$ and Galactic N_H for the serendipitous sources, their contribute to the PDS flux is less than 10%. The LECS data were restricted to the 0.1-4 keV band because of well know calibration problems at higher energies (Grandi et al. 1997).

The PDS spectra were obtained combining the data from the 4 phoswich units. Each pair of detectors is associated to one collimator. The two collimators alternately point at the source and at the background. We extracted PDS spectra using both fixed (FRT) and variable Rise Time (VRT) thresholds to reject background (for details see Fiore, Guainazzi & Grandi 1999). We checked that the second method did not alter the quality of the data or introduce a spurious deficit of high energy photons. No substantial spectral difference between the FRT and VRT spectra was found, so we used the Variable Rise Time spectrum because of its better signal to noise ratio. At the high energy end of the PDS band we excluded channels for which the signal-to-noise ratio was less than 3σ, limiting the upper PDS energy to 120 keV.

Table 1
The observation log

Start time	End time	Exposure [s]			Count rate [s^{-1}][a]		
		LECS	MECS	PDS	LECS	MECS	PDS
1998-09-20 17:01:18	1998-09-22 18:43:24	34572	85596	41613	0.4863 ± 0.004	0.7702 ± 0.003	0.84 ± 0.03

[a]The energy ranges are 0.1–4 keV, 1.5–10 keV, 13–120 keV for LECS, MECS, PDS, respectively. The count rates are background subtracted, and their uncertainties are 1-σ.

Spectral data were then binned using the template files distributed by the *BeppoSAX* Scientific Data Center, in order to ensure the applicability of the χ^2 statistic and an adequate sampling of the spectral resolution of each instrument. LECS, MECS and PDS spectra were simultaneously fitted with XSPEC11, with different relative normalization constants. The MECS constant was fixed to the value 1 and the PDS one was allowed to vary between 0.77-0.83. Since LECS and MECS data partially overlap, the LECS constant was not constrained, allowing the fit routine to find the best value. As discussed by Fiore, Guainazzi and Grandi (1999), this procedure allows to correct the flux miscalibrations among the instruments.

In this paper, the reported uncertainties are at 90% confidence level for one parameter of interest ($\Delta\chi^2 = 2.71$), the fluxes are corrected for absorption and the corresponding luminosities calculated assuming $H_0 = 50$ km sec^{-1} Mpc^{-1} and $q_0 = 0$.

3. Results

3.1. Spectral Analysis

The 3C 382 spectrum is complex and rich in features. As shown in Figure 2, with respect to a power law absorbed by the Galactic column density, $N_H = 7.8 \times 10^{20}$ cm^{-2} (Stark et al. 1992), clear excesses are evident in the soft part of the spectrum (< 2 keV), in the iron line region, and in the hard PDS band. In order to better disentangle the different spectral components, we first analyzed the medium-hard X-ray spectrum (2-120 keV), and then included the soft energy band.

A cutoff power law reprocessed by cold material (Magdziarz & Zdziarski 1995; PEXRAV model in XSPEC) provides a good fit to the 2-120 keV spectrum. We fixed the smaller inclination angle allowed by the pexrav model ($cosi = 0.95$) in agreement with the lower limit of the jet inclination $i > 15°$ inferred by Eracleous and Halpern (1998). We also tested larger inclination angle. The fit is quite insensitive to this parameter for inclination angles $i < 30°$.

Note that a simple cutoff power law does not give a good fit to the data ($\chi^2 = 109.2$ for 81 degrees of freedom); χ^2 is improved significantly by adding a reflection component $R = 0.5$ ($\chi^2 = 76.5$ for 80 d.o.f.). An iron line, even if weak (EW=50 eV), is also required by the data; parameterizing the line with a narrow gaussian profile ($\sigma_{Fe} = 0$), the fit improves significantly ($\chi^2 = 67.0$ for 78 d.o.f., > 99% significant according to the F-test). Even if the intrinsic width of the iron line is let free to vary, the σ value is small and consistent with zero ($\sigma = 0.09^{+071}_{-0.09}$ keV).

With the limited statistics it is not possible to accurately describe the high energy steepening of the power law. In fact, a broken power law (BEXRAV Model in XSPEC) with $\Gamma_{\rm soft} = 1.86$, $E_{\rm break} = 23$ keV and $\Gamma_{\rm hard} = 2.1$ gives an acceptable fit as well (χ^2=65.5 for 77 d.o.f.). Also in this case, the reprocessed features were both weak ($R = 0.5$, EW=50 eV) and the intrinsic width of the line, when free to vary, still consistent with zero.

Finally we included the soft part of the spectrum. The *ROSAT/HRI* data show that 3C 382 is surrounded by an extended hot gas (kT=0.6 (+0.4,-0.1) keV; Prieto 2000). A re-analysis shows that the *ROSAT/PSPC* spectrum (0.1-2.4 keV) is well fitted by a nuclear power law ($\Gamma = 1.7$

Table 2

BeppoSAX Fits[a] to 0.1-120 keV Spectrum of 3C 382

Soft Component = Extended Thermal Emission Only	
Γ_{hard}	$1.89^{+0.02}_{-0.03}$
$E_{\rm cutoff}$ [keV]	207^{+190}_{-75}
Reflection ($\Omega/2\pi$)	$0.7^{+0.3}_{-0.2}$
E_{Fe} [keV]	$6.5^{+0.2}_{-0.1}$
I_{Fe}[b]	$3.2^{+1.7}_{-1.7}$
EW [eV]	46^{+26}_{-24}
kT [keV]	$0.16^{+0.04}_{-0.06}$
χ^2(dof)	163(155)
$\mathrm{Flux}_{0.1-2\ \mathrm{keV}}^{\mathrm{thermal\ component}}$	$1.0^{+0.6}_{-0.4}$[c]
$\mathrm{Flux}_{2-10\ \mathrm{keV}}^{\mathrm{hard\ component}}$	$6.0^{+0.2}_{-0.1}$[c]
Soft Component = Extended Thermal Emission + Power Law	
Γ_{hard}	$1.74^{+0.11}_{-0.20}$
$E_{\rm cutoff}$ [keV]	127^{+99}_{-44}
Reflection ($\Omega/2\pi$)	$0.3^{+0.3}_{-0.2}$
E_{Fe} [keV]	$6.5^{+0.2}_{-0.1}$
I^{a}_{Fe}	$3.4^{+1.7}_{-1.7}$
EW [eV]	48^{+24}_{-25}
kT [keV]	$1.1^{+0.9}_{-1.7}$
Γ_{soft}	$2.9^{+0.6}_{-0.4}$
χ^2(dof)	150(153)
$\mathrm{Flux}_{0.1-2.4\ \mathrm{keV}}^{\mathrm{thermal\ component}}$	$0.15^{+10.50}_{-0.15}$[c]
$\mathrm{Flux}_{0.1-2.4\ \mathrm{keV}}^{\mathrm{soft\ power\ law}}$	$6.4^{+11.4}_{-4.7}$[c]
$\mathrm{Flux}_{2-10\ \mathrm{keV}}^{\mathrm{hard\ component}}$	$6.0^{+0.4}_{-4.0}$[c]

[a] N_H is fixed at the Galactic value, N_H=7.8 × 10^{20} cm^{-2}. The continuum is modeled with a cutoff power law reflected by cold material. The line is a Gaussian with intrinsic width $\sigma_{\rm Fe} = 0$.

[b] Intensity of the iron line in units of 10^{-5} photons cm^{-2} sec^{-1}.

[c] Unabsorbed flux ($\times 10^{-11}$ erg cm^{-2} sec^{-1}).

and $F_{PSPC} \sim 2 \times 10^{-11}$ erg cm^{-2} sec^{-1}) plus a bremsstrahlung component which could account for all the soft excess reported by previous satellites. However, given the uncertainties in the HRI calibration the flux in the extended component is not well known and the determination made using the ROSAT PSPC is ambiguous since it could include a unsolved soft nuclear component. ($F_{HRI} \sim 1.0 \pm 0.7 \times 10^{-11}$ erg cm^{-2} sec^{-1} and $F_{PSPC} = 2^{1.8}_{-0.7} \times 10^{-11}$ erg cm^{-2} sec^{-1}).

In the light of this, we added a thermal model to the PEXRAV model plus a narrow ($\sigma = 0$) iron line. This gives a good fit to the entire 0.1-120 keV spectrum but residuals are still present below 2 keV, indicating the presence of another (or more complex) soft component. Note also that the fitted soft temperature is much lower than required for the extended thermal gas (see Table 2).

The addition of a soft power law ($\Gamma \sim 3$) significantly improves the χ^2 (see Table 2; better than 99.8% significance according to the F test). Note that the thermal component is not required by the data any longer. Its flux is consistent with zero and the temperature cannot be constrained very well (see Table 2). Even if the gas temperature is fixed to the ROSAT value (i.e. kT=0.6 keV), the flux of the extended component is still consistent with zero. During the *ROSAT/PSPC* observation the nuclear component (modeled with a $\Gamma = 1.7$ power law) was about a factor 2 lower that during our observation, so it is possible that the extended component is washed out by the strong continuum and therefore only marginally detected by *BeppoSAX* . (The extended component would not have varied on the time scale of years.) Other thermal models, such as a black body, can also be used to fit the LECS excess instead of a simple power law. However the poor spectral resolution of *BeppoSAX* below 1 keV makes this a useless exercise because the different models are not statistically distinguishable.

We conclude that a hot extended plasma emission alone can not explain all the soft luminosity observed by *BeppoSAX* . Another softer and stronger nuclear component is necessary.

Once defined the best model for the entire *BeppoSAX* spectrum (thermal emission plus and power law component plus cutoffed power law and reflection), we came back to the iron line study. We allowed the intrinsic width (σ) of the line to vary. Also in this case we found σ consistent with zero, being estimated from the fits as 0.04 (-0.04,+0.48) keV.

3.2. Iron Line Historical Study

One of the most striking results of the previous section is the weakness of the iron line and the reflection component, independent of what model was used to fit the continuum.

Since both the iron line and the reflection are weak, it makes sense to imagine the line arising in the same material that reflects the primary X-ray radiation. In order to understand the location of this reprocessing material, we investigated the iron line variability using data from the literature.

If the iron-emitting material is a standard cold disk with a hot corona above it, a strong correlation between continuum and reprocessed features is expected. Conversely, if either a non-thermal jet contaminates the X-ray continuum or the reprocessing gas is not near to the primary X-ray source, the continnum and line should not change together.

In Figure 3 the 2-10 keV continuum flux and the iron line flux are plotted vs. the the date of observation. The data are from *Ginga* (Woźniak et al. 1998), *RXTE* (Eracleous, Sambruna and Mushotzky 2000) and *BeppoSAX* (this paper). We did not use the *ASCA* data, in which the iron line was broad and intense (Reynolds 1997). As discussed by Zdziarski and Grandi (2001) for the 3C 120 case, the discrepancies between *BeppoSAX* /*RXTE* and *ASCA* are likely due to the *ASCA* continuum being not well parameterized, either because of (i) the limited energy band covered by *ASCA* , and consequently the inability to resolve all the spectral components, or (2) calibration problems among the different instruments, as reported by *ASCA* team. It is known that the SIS CCDs suffer from serious degradation at energies below 1 keV and that the SIS and GIS results also diverge. These problems were already present, although not understood, since 1994 [1].

Figure 3 shows clearly that, while the contin-

[1] *ASCA* Calibration problems are reported on the web page heasarc.gsfc.nasa.gov/docs/asca/wachout.html and discussed in the *ASCA* -*BeppoSAX* intercalibration report available on the *BeppoSAX* webpage: www.sdc.asi.it/software.

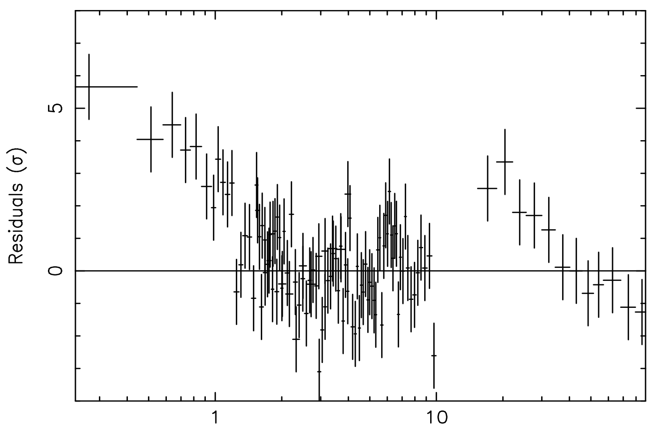

Fig. 2.— Residuals to a simple power-law model absorbed by Galactic N_H. A strong soft excess is apparent below 1 keV, as are an iron line and a hard excess above 10 keV.

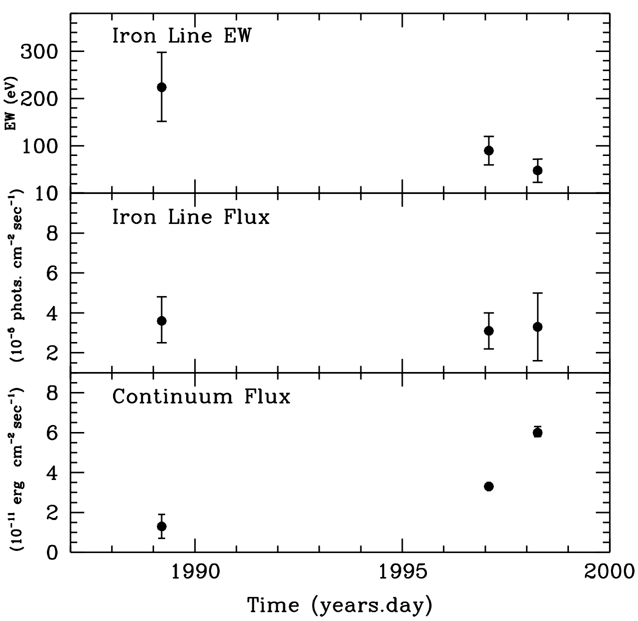

Fig. 3.— 2-10 keV continnum flux (lower panel), iron line flux (middle panel) and Equivalent Width (upper panel) of 3C 382 over 9 years of X-ray observation. Data are from *Ginga* (Woźniak et al. 1998), *RXTE* (Eracleous et al. 2000) and *BeppoSAX* (this paper). The reported error bars correspond to 90% confidence levels for one parameter of interest. The line flux appears independent of the continnum level.

uum flux changed by about a factor 5 over a 9-year period, the number of photons emitted in the fluorescence line varied little (by less than a factor of 2). This result has a very important implication: it shows that the cold matter does not respond promptly to variations of the primary continuum.

In principle, the increase in continuum flux could be due to beamed jet radiation which dilutes the Fe emission of a stationary underlying (Seyfert-like) accretion disk. As discussed in the next section, there are other (radio-optical-UV) results which argue against the jet hypothesis in this source. Therefore we interpret Fig. 2 as implying a spatial separation between X-ray source and reprocessing matter.

Note that similar results, based on repeated *BeppoSAX* observations, have been obtained for another radio galaxy, Centaurus A (Grandi et al. 1998). In this source, the iron line appeared more intense when the nuclear source was at the lower intensity level, supporting the idea that the reprocessed features are produced far away from the primary X-ray source.

Given the scarce sampling of the continuum and the iron line flux, it is difficult to estimate the effective temporal lag (and therefore the distance between reprocessing gas and X-ray source). However the historical data support the idea that the reprocessing site is located at light years (parsecs) away from the X-ray primary source and coincides with a dense molecular torus.

Ghisellini, Haardt and Matt (1994) studied the contribution of an obscuring torus seen on axis to the X-ray spectrum and showed that, for column density $N_H \geq 10^{24}$ cm^{-2}, an important fraction of the hard X-ray radiation is reprocessed. The produced iron line is narrow and weak (80-100 eV) and the reflection component is 29-50% of the total flux at 30 keV. Our data agree with these predictions within the uncertainties.

In addition the *BeppoSAX* data indicate that line is narrow. For any tested model of the continuum, the best fit parameter of the intrinsic width is always less than 90 eV and consistent with zero. A narrow line is expected if the emitting gas is slowly rotating matter at parsec distances.

4. Discussion

The *BeppoSAX* X-ray spectrum of 3C 382 has provided a wealth of interesting results. We find:

- (1) a soft component not associated with the extended thermal emission detected by *ROSAT* ;
- (2) a medium-hard continnum well modeled with a cutoff power law ($E \sim 120$ keV) or a broken power law ($E_{break} \sim 30$ keV);
- (3) a weak narrow iron line; and
- (4) a weak reflection component.

Both the iron line and reflection component are significantly weaker that those observed in Seyfert 1 galaxies. In addition, X-ray spectra of 3C 382 taken from the literature show that the continuum and the iron line do not change together.

4.1. The Continuum Emission

In order to interpret these results, the first question is, how is the X-ray continuum emission produced? In the most popular scenarios for radio-loud AGNs, there are two possible origins for the X-ray emission:

- (i) Comptonization of seed photons by hot rarefied gas. The reprocessed region can be a patchy corona above a thin optically thick disk (Haardt & Maraschi 1991, 1993; Poutanen & Svensson 1996) or a hot inner accretion flow and a cold outer thin disk (Shapiro, Lightman & Eardley 1976; Narayan, Mahadevan & Quataert 1998).
- (ii) Synchrotron and inverse-Compton radiation from relativistic electrons in a collimated outflowing plasma. The seed photons responsible for the inverse Compton component can be the synchrotron photons originating within the jet (SSC; Maraschi, Ghisellini & Celotti 1992, Bloom & Marscher 1993) or photons external to the jet, produced by the accretion disk and/or the Broad Line Regions (EC; Sikora, Begelman & Rees 1994).

It is likely that the former process is at work in radio-quiet AGNs, the latter in blazars.

Broad-Line Radio Galaxies are believed to be intermediate objects because they show broad optical-UV lines but also contain well collimated radio jets. The question is then whether the observer sees X-ray photons from the jet or the accretion flow radiation or both. In 3C 382, there are hints that there is no strong jet contamination at optical-UV and X-ray wavelengths. Yee and Oke (1981) found an optical nuclear continuum which followed a power law ($\propto \nu^{\alpha}$) with alpha=+1.2 and -0.7 shortward and longward H_{β}, respectively. They suggested that the upturn at the blue end could be the UV bump from the accretion disk, a feature commonly observed in Seyfert galaxies. Moreover the blue continuum in 3C 382 is only weakly polarized, whereas strong polarization would be expected if the contribution of beamed synchrotron radiation were significant (Antonucci 1984, Cohen et al. 1999). HST observations of broad-line FRII galaxies also support the idea of relatively weak optical jet emission: while optical cores are found in a number of these galaxies, including 3C 382, their luminosities are poorly correlated with the radio luminosities (Chiaberge, Capetti & Celotti 2000). Compared to FRIs with similar radio luminosities, BLRGs appear much brighter in the optical, consistent with emission from an accretion disk contributing significantly in these sources.

Canosa et al. (1999) found a strong linear correlation between core radio luminosity (at 5 GHz) and unresolved *ROSAT/HRI* luminosity for a sample of B2 radio galaxies (mostly FRIs). (Similar results in Einstein data for a smaller and heterogeneous sample were found by Fabbiano et al. 1984) Interestingly, 3C 382 is the only source in the B2 sample with an X-ray luminosity about 100 times larger than the correlation would predict. Canosa et al. (1999) argued that X-rays from 3C 382 must include strong X-ray emission from an unbeamed nuclear component, likely related to the accretion disk.

Our *BeppoSAX* data, together with simultaneous *EXOSAT* and *IUE* data (collected on 1983 September 12; Barr & Giommi 1992; Tadhunter et al. 1986), also support the idea of a strong disk contribution in 3C 382, as can be seen from the UV to X-ray spectral distribution in Figure 4. The UV flux can change by more than a factor 7 on a time scale of years (Tadhunter et al. 1986).

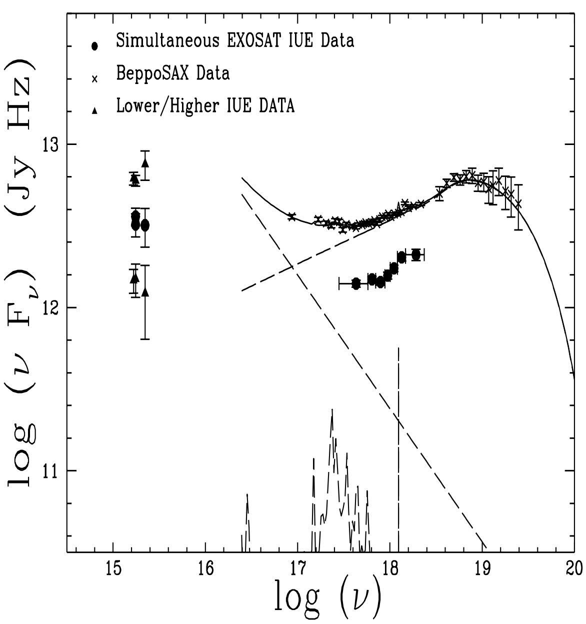

Fig. 4.— The UV to X-ray spectral energy distribution of 3C 382. The solid line represents the best fit to the *BeppoSAX* data (crosses), as reported in Table 1, and the dashed lines are the individual spectral components (e-folding power law plus reflection, iron line, soft power law, and weak thermal emission). We suggest the UV bump and soft X-ray excess are produced by a cold accretion disk. Filled circles represent an earlier, simultaneous *IUE* (Tadhunter et al. 1985) and *EXOSAT* observation (Barr & Giommi 1992), in which both the disk emission and X-ray component are ~ 2 times fainter. Filled triangles represents the lowest and highest *IUE* fluxes measured by Tadhunter et al. (1985).

Therefore, to represent the full range of UV variability, Figure 4 also shows the lowest and highest fluxes measured by *IUE* . The obvious UV/X-ray excess can be interpreted as accretion disk emission plus a hard Comptonized tail extending into the soft X-ray band.

Finally, we note that the spectral break at high energies observed in the *BeppoSAX* spectrum also argues against the blazar picture. According to unified schemes for radio-loud AGN (Urry & Padovani 1995), BLRGs and intrinsically powerful blazars are the same objects seen at different viewing angles, in which case the jet output in the *BeppoSAX* energy range should be inverse Compton (Fossati et al. 1998, Ghisellini 1998). However, it is unlikely that the high energy cutoff in 3C 382 is a Compton peak, which in powerful blazars appears at MeV-GeV energies.

On the contrary, a power law which cuts off at high energies is expected in Comptonization models, being related to the temperature of thermal electrons which scatter soft photons (Haardt & Maraschi 1991, 1993; Poutanen & Svensson 1997). The e-folding energy for 3C 382 is at a value typical of those for Seyfert 1s (Matt 2001). We therefore conclude that the X-ray continuum in 3C 382 is produced mainly by processes related to an accretion flow rather than non-thermal relativistic plasma in a jet.

4.2. Weak Reprocessing Features

The presence of a UV bump and soft X-ray excess indicates that the accretion material has to be cold and optically thick. When a cold slab is illuminated by a X-ray source, it produces an iron line and a reflected component (Matt, Perola & Piro 1991; George & Fabian 1991), which we should therefore expect to see in 3C 382. If instead the bulk of the reprocessed radiation comes from much larger regions, as suggested by the lag between continuum and iron line (Fig. 3), this means the cold accretion flow has somehow been inhibited from producing these characteristic spectral features.

One possible explanation is that the surface of the thin, optically thick disk (Shakura & Sunyaev 1970) is highly ionized. Nayakshin and Kallman (2000) have recently investigated how the ionization of deeper and deeper layers of the accretion

disk can affect the reprocessed features. They showed that, if the X-rays are produced in magnetic flares at few disk scale heights, iron can be almost completely ionized providing the X-ray luminosity is a good fraction of the Eddington luminosity (L_{Edd}). In that case, the skin of the disk acts as a perfect mirror and the reflected continuum is featureless. Following their prescription, we calculated a lower limit for the accretion rate for 3C 382, $\dot{m} = L_{tot}/L_{Edd} > 6 \times 10^{-3}$. The total luminosity, $L_{tot} = L_{UV} + L_X \sim 5 \times 10^{45}$, was deduced from the simultaneous *IUE* and *EXOSAT* data reported in Fig. 4 assuming a high energy cutoff and a reflection strength as measured by *BeppoSAX* . The Eddington luminosity was calculated assuming an upper limit for the black hole mass ($M < 7 \times 10^9\ M\odot$; Tadhunter, Perez & Fosbury 1986). In agreement with the magnetic flare geometry investigated by Nayakshin and Kallman (2000), the lower limit for the 3C 382 accretion rate is sufficient to obtain a completely ionized mirror-like disk. Then the bulk of observed emission line can entirely come from a molecular torus.

Another possibility, which preserves the model of a cold disk, is that the hot corona has a mildly relativistic motion directed away from the disk (Beloborodov 1999a, 1999b). A soft photon of energy ϵ_s passing through the hot corona acquires on average an energy Aϵ_s. Beloborodov has calculated A as a function of the plasma bulk motion $\beta = v/c$ (see Fig. 1 in Beloborodov 1999a). The spectral slope, Γ, depends on the amplification factor, roughly as $\Gamma \sim 2.33(A-1)^{-0.1}$ (see also Fig. 2 in Beloborodov 1999b). The spectral index $\Gamma = 1.7-1.8$, as for 3C 382, implies a Comptonization factor $A \geq 14$, which in turn implies $\beta > 0.4$ for hemisphere and slab geometries of the corona, i.e., a mildly relativistic flow. The effect of the relativistic motion is to reduce the strength of the reflection. For $\beta \geq 0.4$ and small angle of view the radiation reflected (R) from the cold slab becomes negligible ($R < 0.1-0.2$). In a similar way, mildly relativistic motions of the corona can influence the iron line features. As shown by Reynolds and Fabian (1997), it is sufficient that a plasma flows with $\beta \geq 0.4$ to reduce the equivalent width of the iron line by more than a factor 10. Also in this case, if the disk production of the line is strongly inhibited, the main reprocessing region can be a molecular torus.

Note that an outflowing corona model could also account for the weak features of 3C 120 (Zdziarski & Grandi 2001). This hypothesis is particularly attractive for radio-loud AGNs. A hot plasma with a mildly relativistic velocity is not unlikely in sources that produce strong jets in their nuclear regions.

5. Conclusions

The X-ray continuum of 3C 382 in a bright state derived from a long *BeppoSAX* observation is similar to that of Seyfert galaxies, i.e. a power law with index $\Gamma = 1.74$, with an e-folding cutoff at about 120 keV. At soft energies, an excess of soft photons is detected that can not be accounted for by an extended thermal component alone. The additional soft component required by the *BeppoSAX* data could be due to thermal emission from the innermost regions of a Shakura-Sunyaev disk.

Although a cold disk may be present, it must for some reason be inhibited from producing features. The iron line and the reflection are both detected, but they are weak and the iron line is unsolved by *BeppoSAX* . This, plus the lack of correlation of the Fe line with the continuum flux, suggests the cold reprocessing material is far from the primary X-ray source. It could be a dense molecular torus thought to surround the central source in many AGN ($N_H \geq 10^{24}$ cm^{-2}). We discussed two possibilities that can explain the suppression of features in the vicinity of the black hole: (i) the upper layers of the disk are completely ionized, or (ii) the patchy corona above the disk is not static but flowing away with mildly relativistic velocity.

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